DOE Hydrogen Program
Technology Validation Sub-Program

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Project #: TV1

Objectives

Validate integrated hydrogen and fuel cell technologies for transportation, infrastructure, and electric generation in a systems context under real-world operating conditions.

- By 2005, $3.60/gge and 8¢/kWh.
- By 2008, 20,000 hour fuel-cell durability (stationary), 32% efficiency, $1,500/kW
- By 2009, 250+ mile range, 2000 hour fuel-cell durability (vehicle), $3.00/gge hydrogen (untaxed)
- By 2011, biomass/wind or geothermal electrolyzer-to-hydrogen system to produce hydrogen for $2.85/gge at the plant gate

Tasks

Task 1 Vehicle Field Evaluations

Task 2 Hydrogen Infrastructure – Power Parks

Task 3 Natural Gas-to-Hydrogen Refueling Stations

Task 4 Co-Production of Hydrogen and Electricity

Task 5 Renewable Hydrogen Production Systems

Task 6 Technical Analyses

Budget

Task		DOE		Cost Shares
		EW&D	Interior	
1	Fleet & Infrastructure	$6,359,761	$16,713,129	$21,781,890
2	Power Parks	$720,000		$720,000
3	Natural Gas to H2 Refueling Stations	$1,178,355		$878,355
4	Energy Station	$350,000		$350,000
5	Renewable	$0		$0
6	Analyses	$250,000	$351,000	$0
1&4	Earmarks	$5,059,000		$5,059,000

Congressionally Directed Projects

California Infrastructure	$4,960,000 (2005)	Tasks 1 & 4	Develop, build, and test hydrogen infrastructure
Locomotive fuel cell	$300,000 (2005)	Task 1	Develop, build & test underground H2 mine loader
Bus Evaluation	$99,000 (2005)	Task 1	Analyze zero emissions bus – Santa Clara, CA
Univ. of Alabama Birmingham	$963,372 (2003)	Task 1	Test stationary and vehicle hydrogen systems
Hawaii Energy Center	$992,000 (2005) $2,982,000 (2004)	Task 2	Develop fuel cell test center
Hawaii Power Park	$490,539 (2004)	Task 2	Build and test power parks

Congressionally Directed Projects
Continued

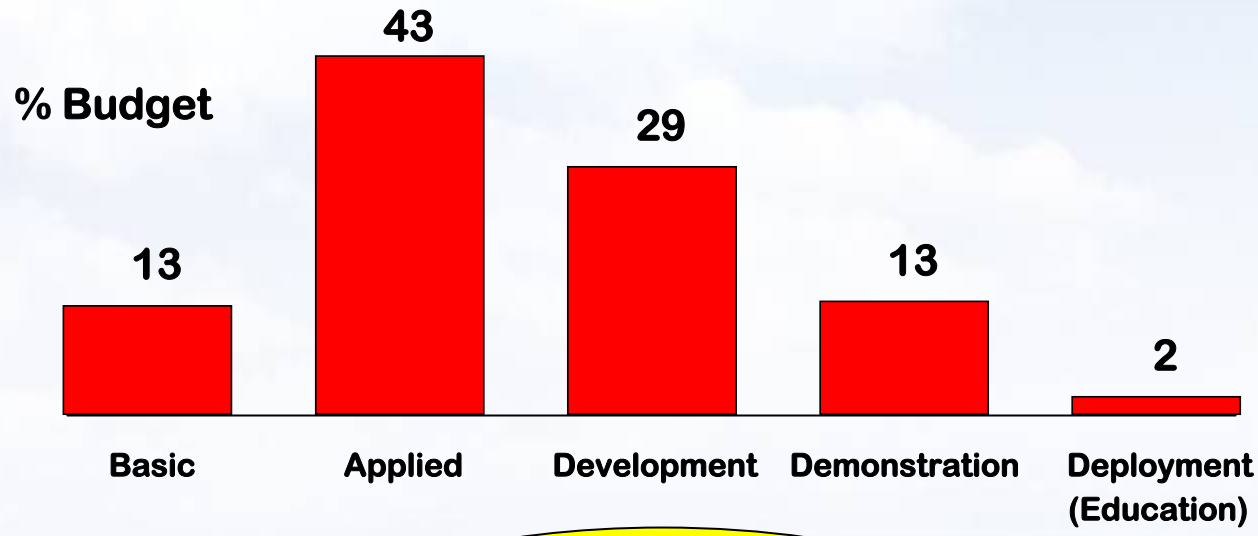
NEXT Energy	$793,096 (2003)	Task 2	Build and test refueling station
Chattanooga	$2,485,250 (2004)	Task 4	Develop, build and test solid oxide fuel cell coproduction system
Washoe County	$1,962,155 (2004) $992,000 (2005)	Task 5	Develop, build & test geothermal/ electrolyzer refueling station
UNLV	$963,372 (2003)	Task 5	Build and test photovoltaic refueling station
Florida Hydrogen Partnership	$1,962,155 (2004)		Hydrogen research and development

Barriers

A	Vehicles	• statistical data for vehicles that are operated under controlled, real-world conditions (i.e., fuel economy, cold start efficiency, stack degradation, system durability) • vehicle drivability, operation and maintenance	
B	Storage	• driving range • cost	• composite tank operating cycle life and failure
C	H_2 Refueling Infrastructure	• capital costs to build and install	• footprints • system availability
D	Hydrogen and Electricity Coproduction	• statistical data on cost and durability of hydrogen fuel cells and reformer systems • development of safety procedures • codes & standards development • availability, operation and maintenance experience	
E	Maintenance & Training Facilities	• limited certified procedures • limited trained personnel • lack of data on operation and maintenance costs	
F	Codes & Standards	• statistical data for codes and standards development • need development of safety procedures (i.e., HAZOP and FMEA) • global standards need to be established	
G	Hydrogen from Renewable Resources	• durability, cost and efficiency for integrated renewable electrolysis systems • biomass feed system, catalyst lifetimes	

Balanced Program is Being Implemented

FY 2005: Requested DOE Hydrogen Program Budget, by Category ($227M)

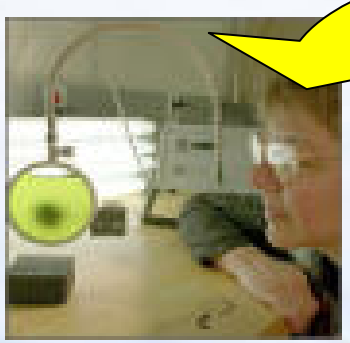


H_2 Production

H_2 Delivery

H_2 Storage

Fuel Cells



Basic & Applied Research

Technology Development

Systems Analysis & Integration

Safety, Codes & Standards

Education

Technology Validation through "Learning Demonstrations"

Task 1 – Vehicle Field Evaluation "Learning Demonstration"

Description

- Support CaFCP vehicle and bus demonstration
- Support Controlled Fleet demonstrations (collect vehicle operating experience from different geographic regions)
- Design, build and test hydrogen locomotive and front-end loader vehicles

CaFCP Bus Demonstration

Hickam Air Force Base

California Fuel Cell Bus Demonstration Sites

SunLine Transit Agency

Santa Clara Valley Transportation Authority

Alameda Contra-Costa Transit Agency

- Completed evaluation of ThunderPower bus at SunLine
- Data collection in progress at Santa Clara VTA and Hickam AFB
- Infrastructure in place for the Alameda Contra-Costa Transit Agency

Technology Validation Strategy

- Conduct learning demonstrations of hydrogen infrastructure in parallel with hydrogen fuel cell-powered vehicles to enable and assess technology readiness for a 2015 commercialization decision.

Major Objectives

- Obtain detailed component data under real-world conditions (climatic, geographic etc.) to re-focus the Department's hydrogen and fuel cell component and materials research

- Validate the technology against time-phased performance-based targets

Learning Demonstration Description and Performance Targets

- FY 2004 – 2009 Project Period
- Government/industry cost shared co-operative agreement
- $190M Government share subject to the appropriations process
- 2 Generations of vehicles
- Cold climates to be included by 2nd generation
- Renewable feedstock for H2 generation included
- Codes, Standards and Education integral to the success of the project
- Stationary facilities that co-produce electricity and hydrogen are included

Key Targets

Performance Measure	2009*	2015**
Fuel Cell Stack Durability	2000 hours	5000 hours
Vehicle Range	250+ miles	300+ miles
Hydrogen Cost at Station	$3.00/gge	$1.50/gge

*** To verify progress toward 2015 targets**
**** Subsequent projects to validate 2015 target**

Cooperative Agreements Have Begun

(1)

(1)

Awarded 4 cooperative agreements
1 project in negotiation

(1) Fuel cells supplied by Ballard

Data Collection & Analysis Process

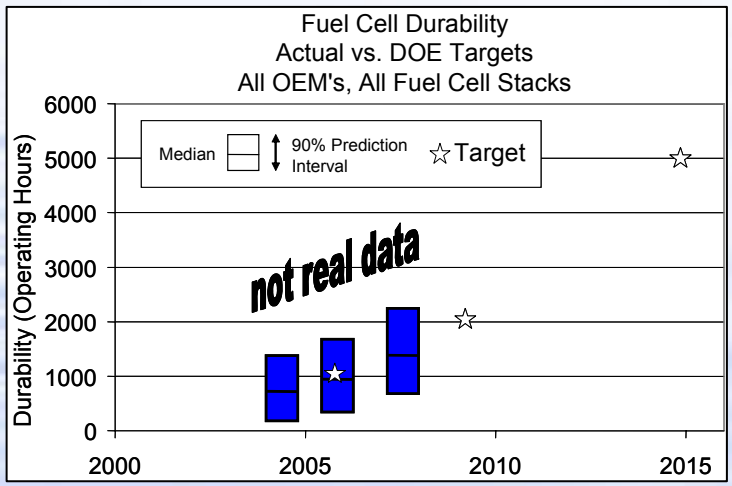
Developed Secure Data Center and composite data products

Raw Data, Reports

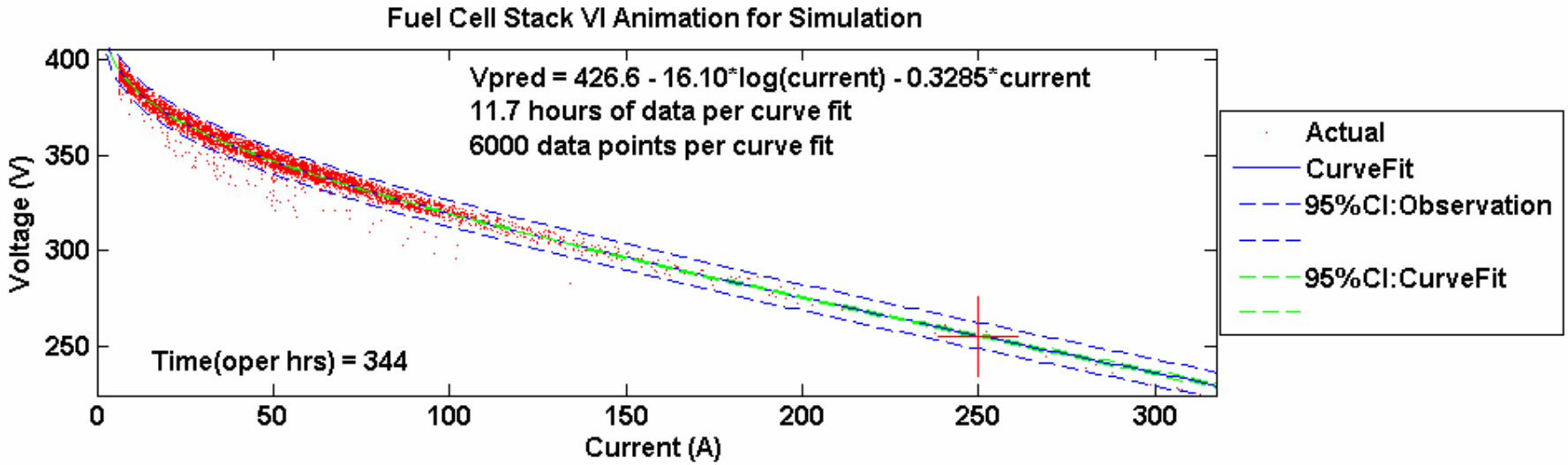
- @ NREL: Strictly Controlled Access
- Detailed Analyses, Data Products, Internal Reports
- HSDC ADVISOR

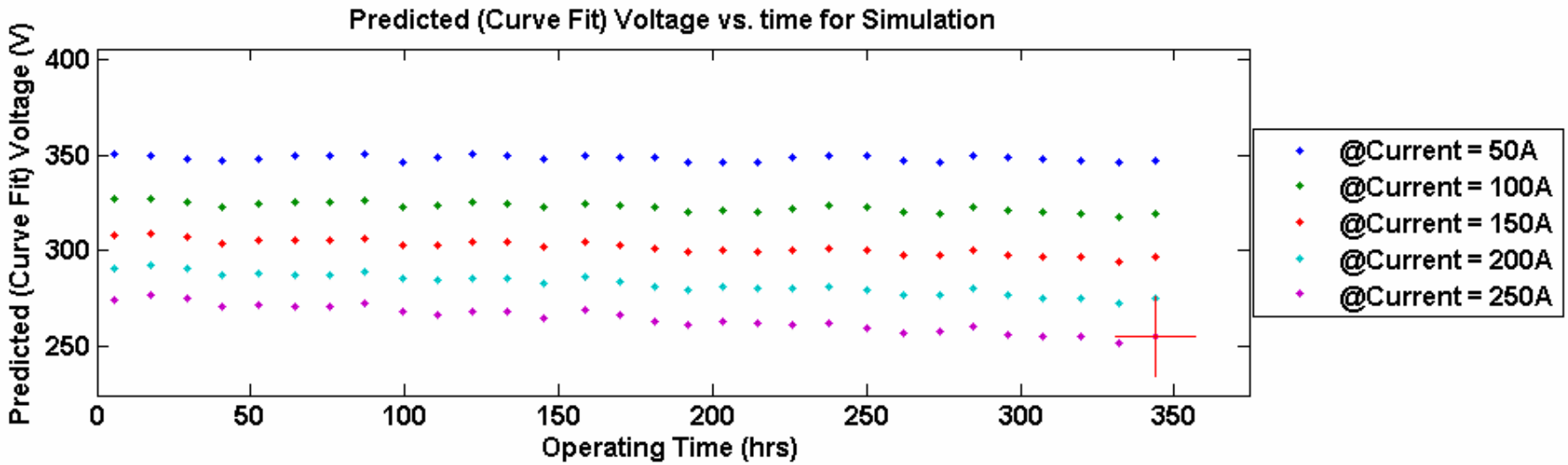
Composite Data Products

- Pre-Agreed Upon Aggregate Data Products
- No Confidential Information



Analysis Example: Stack Degradation





not real data

Hydrogen Vehicles

By 2009, 250+ mile range, 2000 hour fuel cell durability

Vehicles have been delivered and data collection has begun

Hydrogen Refueling Infrastructure

By 2009, <$3.00/gge hydrogen, untaxed

Photos: DTE

DTE/BP Power Park, Southfield, MI

LAX refueling station

Hydrogen and gasoline station, WA DC

Photo:Shell Hydrogen

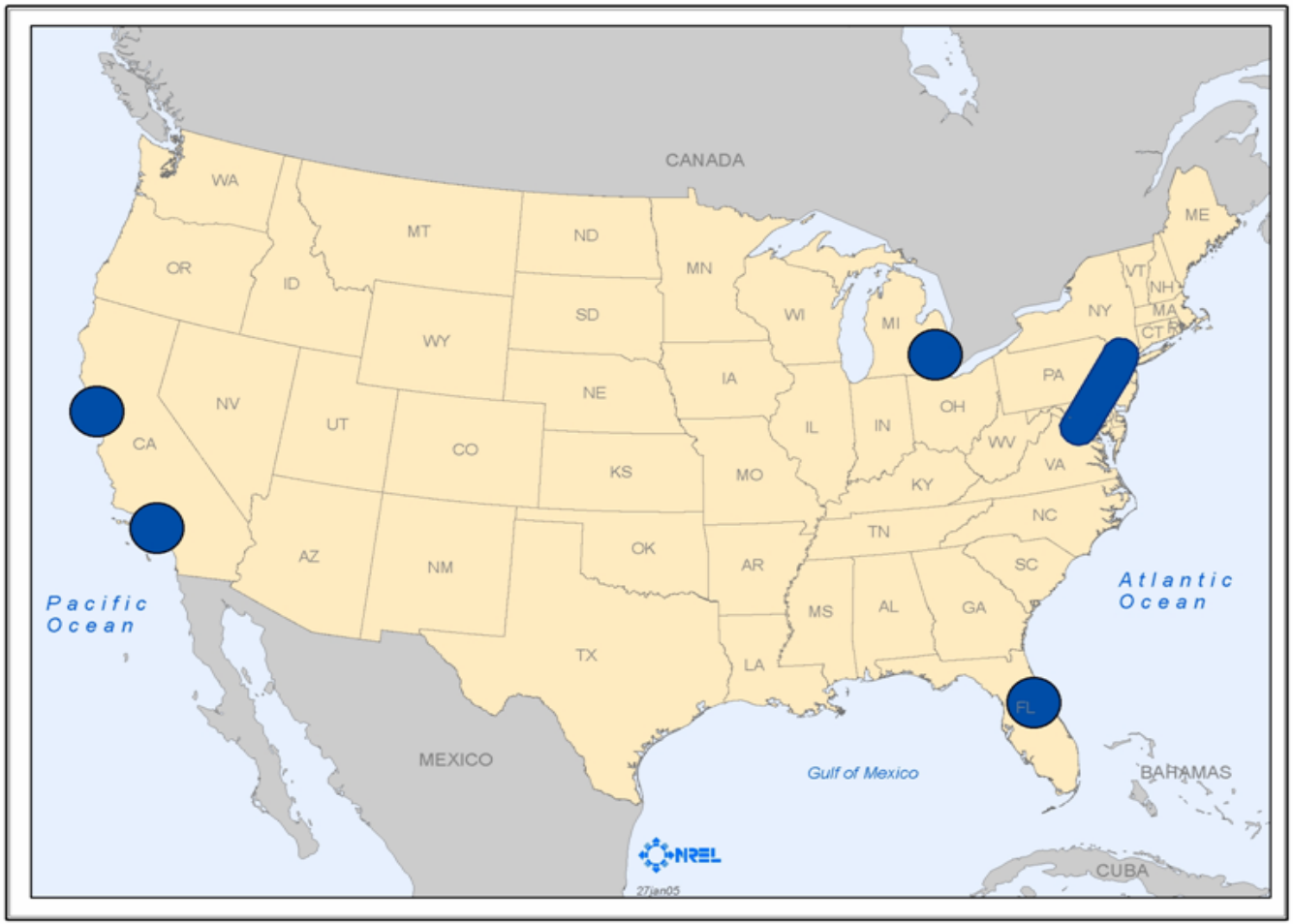
Chino, CA

Photo: H2CarsBiz

Hydrogen Refueling Stations Opened in California, Michigan and Washington D.C.

Data Collection

Diverse Geography Addresses Four Key U.S. Climates



Cold, Moderate, Hot/Humid, Hot/Arid Climates

Hydrogen Locomotive and Front End Loader Vehicles Accomplishments

Accomplishments:

- Completed testing of hydrogen locomotive
- Completed detailed engineering design, review and risk assessment for front end loader
- Completed fabrication and testing of fuel cell power plant for front end loader
- Other subassembly fabrication in progress including metal hydride storage for front end loader

Task 2 – Hydrogen Infrastructure Power Parks

By 2008, 20,000 hour fuel-cell durability (stationary), 32% efficiency, $1500/kW
By 2008, 68% efficiency (electrolyzer stack) and $600/kW

Description

- Design and construct early refueling facilities on integrated renewable/fossil systems
- Document permitting requirements, lessons learned and safety plans
- Collect and disseminate operating data from different geographic regions

Task 2 – Hydrogen Infrastructure Power Parks

By 2008, 20,000 hour fuel-cell durability (stationary), 32% efficiency, $1500/kW

Photos: DTE

DTE/BP Power Park
Southfield, MI

Motor Vehicle Refueling

Refueling Events

Hydrogen	236
CHyNG	717
CNG	2,938
Total	3,891
Accidents	0

Fuel Dispensed*

Hydrogen	259 kg
CHyNG	2,378 gge
CNG	14,218 gge

** Dispensed amounts are from credit card transactions.*

Accomplishments:

- Power Park installed and operated that is capable of producing 60 kg/day and 400 kwhr/day. Utilize solar and biomass electrolysis systems. Dispense 5000 psi hydrogen at 99.995% (DTE)
- The hydrogen side of pilot park has a 99.33% availability during 26,000 calendar hours of operation and 8500 hours of electrolyser operation (APS)
- Fuel cell and ICE gen sets operating produced 9.6 MWH of power (APS)
- Pearson 5 tpd gasifier using bagasse tested (Hawaii)
- Initiated testing on Ballard and GM fuel cells (Hawaii)

Task 3 – Natural Gas-to-H_2 Refueling Stations

By 2006, validate $3.00/gge

Description

- Build and operate natural gas-to-hydrogen refueling station to collect data on reformer performance and reliability
- Validate the cost of H_2 produced including station operation and maintenance
- Disseminate data from refueling sites to verify component performance

Task 3 – Natural Gas-to-H_2 Refueling Stations

By 2006, validate $3.00/gge

Accomplishments:

- Completed Phase 2 subsystem development for all components of an advanced SMR. Final system design efforts and equipment procurement initiated. Liquid hydrogen tank and blend and dispenser systems installed. (APCI)
- Completed subsystem and system designs. Second generation fuel processor built and tested. Developed hydrogen dispenser fill control algorithm. (GTI)
- Completed Phase 2 development of an autothermal cyclic reformer pilot scale reformer and PSA subsystem. Both systems have been operated to finalize Phase 3 system design. (GE)
- Autothermal reformer tested at SunLine to supply hydrogen for demonstration buses in revenue service. (Hydradix)
- Design and component testing completed on isothermal compressor. (APCI)

Task 4 – Co-Production of H_2 & Electricity

By 2005, validate 8¢/kWh and $3.60/gge

Description

- Collect data on reformer and fuel cell performance, reliability and cost
- Identify the operation and maintenance requirements for the Energy Station
- Determine the economics for a large co-production refueling station

Task 4 – Co-Production of H_2 & Electricity

By 2005, validate 8¢/kWh and $3.60/gge

Accomplishments:

- Successfully demonstrated 2,000 hour run on hydrogen generator (Las Vegas)
- Installed and initiated operation of commercial fuel cell system (DTE)
- Designed and initiated procurement of second generation hydrogen generator (Penn. State)
- Go decision made to proceed with engineering development and preliminary design of high temperature fuel cell concept (APCI)
- 5 kW solid oxide fuel cell system design completed. Component assembly and testing initiated. (Chattanooga)
- Bus successfully operated on 30%/70% hydrogen/natural gas blend (Las Vegas)

Task 5 – Renewable H_2 Production Systems

By 2011, validate $2.85/gge at the plant gate from biomass/wind or geothermal resource

Description

- Validate integrated systems and their ability to deliver hydrogen
- Collect data to verify component performance

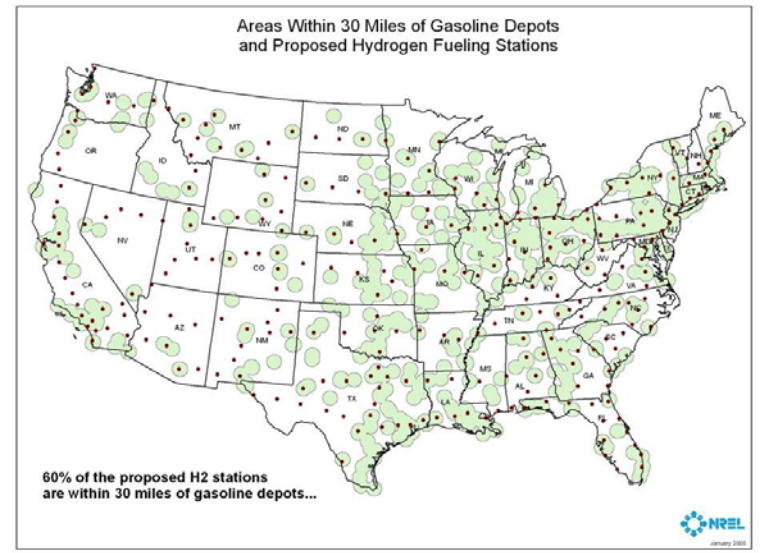
Task 5 – Renewable H_2 Production Systems

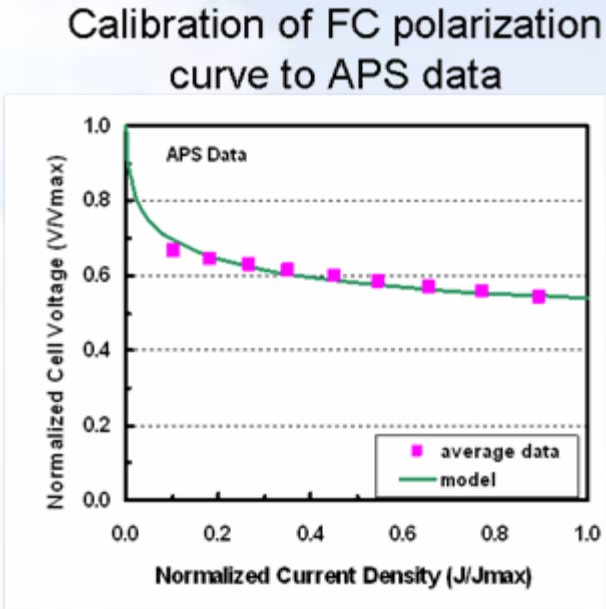
By 2011, validate $2.85/gge at the plant gate from biomass/wind or geothermal resource

Accomplishments:

- Completed construction and preliminary testing of biomass-to-hydrogen pyrolysis-reformer pilot plant (Clark Atlanta University)
- Identified potential co-products option (University of Georgia)
- Safety and component performance review completed (University of Georgia)
- PV hydrogen station design completed (UNLV)

Task 6 – Technical Analyses





Description

- Analyze early infrastructure deployment options
- Analyze advanced Power Parks for production of hydrogen and electricity

Accomplishments

- Early hydrogen infrastructure analysis completed for several scenarios
- Power Park validation analyses for several stations is completed

Future Work

Task 1 Complete testing and analysis of generation 1 vehicles and operation and analysis of infrastructure

Continue data collection on VTA, Hickam, AC Transit and SunLine buses

Complete front end loader test program

Task 2 Complete the installation and operation of 3 power park projects

Task 3 Complete validation of 3 natural gas to hydrogen refueling stations projected to produce hydrogen at less than $3.00/gge

Future Work Continued

Task 4	Complete validation of energy station projected to produce hydrogen at less than $3.60/gge and 8¢/kWh
	Continue with high temperature coproduction systems
Task 5	Complete 1000 hour durability and performance tests of biomass pyrolysis system
	Complete construction and testing of PV hydrogen refueling station
Task 6	Complete analysis of power park systems and define market applicability
	Continue development of early infrastructure scenarios